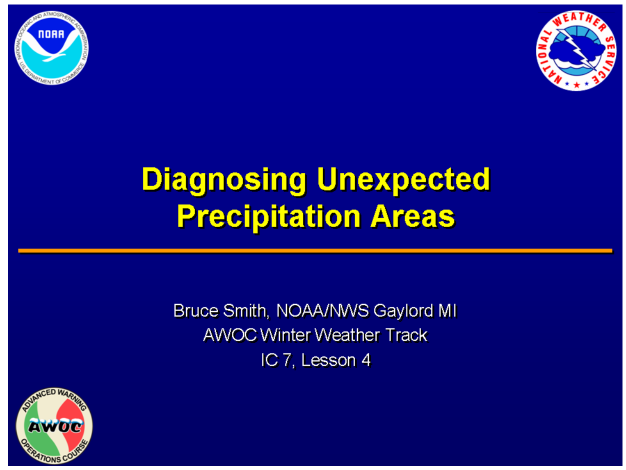
1. IC7.4: Diagnosing Unexpected Precipitation Areas

Instructor Notes: The title of this lesson is "Diagnosing Unexpected Precipitation Areas". It will take approximately 30 minutes to complete. My name is Bruce Smith, Science and Operations Officer at Gaylord, Michigan.

Student Notes:



2. Unexpected Winter Precipitation

Instructor Notes: When winter precipitation develops, or changes character and intensity in ways that differ from the current forecast, it is critical that forecasters work quickly to understand the reason the precipitation is occurring, and to determine how long it will persist, so that winter weather headlines can be accurately addressed. A methodology for dealing with unexpected winter precipitation is covered in this lesson. It is the 4th lesson of Instructional Component 7, "Monitoring System Evolution". Through the use of a case study, a methodology will be demonstrated to recognize and respond to unexpected precipitation. The role of observational data, and the utilization of effective diagnosis and short term forecasting techniques will be emphasized. Every operational forecaster should be able to efficiently execute this methodology, so that quick and decisive action can be taken to improve the forecast.

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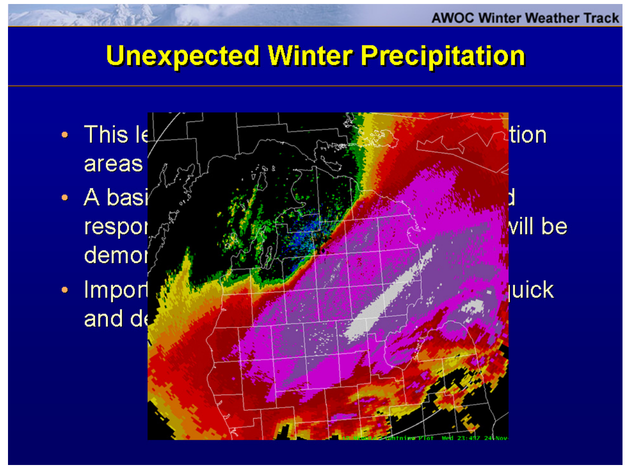

3. Prerequisite Material

Instructor Notes: The following instructional material previously presented in the Winter Weather Advanced Warning Operations Course can be considered background material for this lesson.

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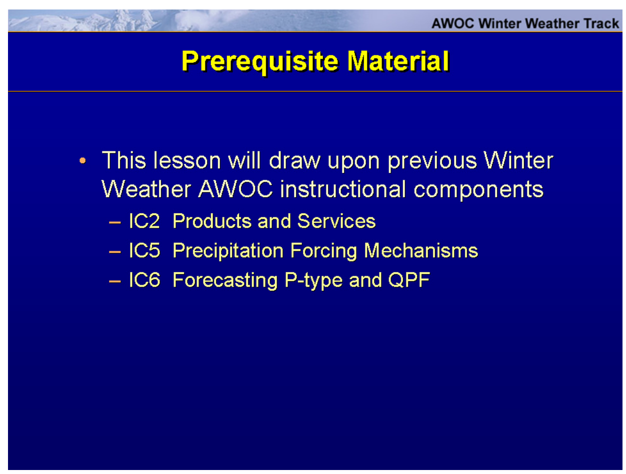

4. Lesson Outline

Instructor Notes: This lesson will be broken down into two sections. In section one, a methodology for handling unexpected precipitation areas will be described. It is comprised of five basic steps. These steps make up the recognition phase and the response phase of the methodology. Finally, in section two of this lesson, the methodology will be applied to a short case study.

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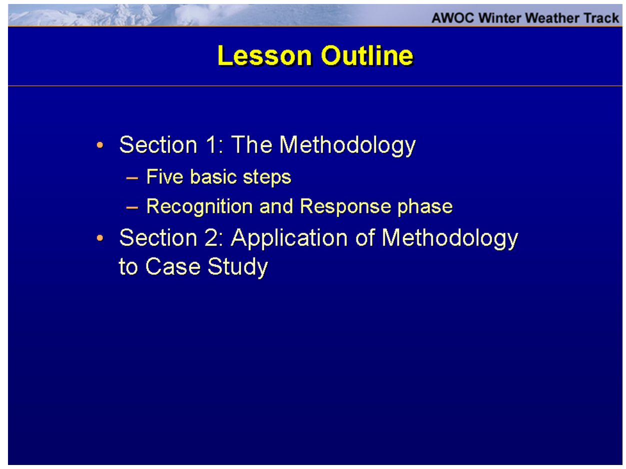

5. Learning Objectives

Instructor Notes: At the end of this lesson, you will be able to accomplish the following learning objectives: First, you will be able to describe why a methodology for responding to unexpected precipitation is important. Next, you will be able to identify the steps comprising this methodology. Lastly, you will be able to identify which steps are associated with the recognition phase of the methodology, and which are associated with the response phase of the methodology.

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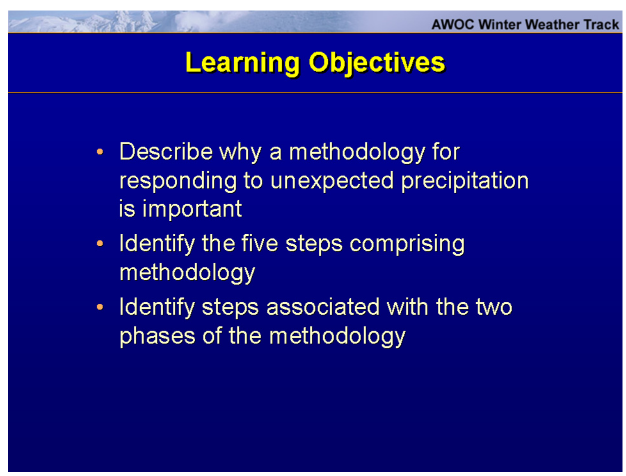
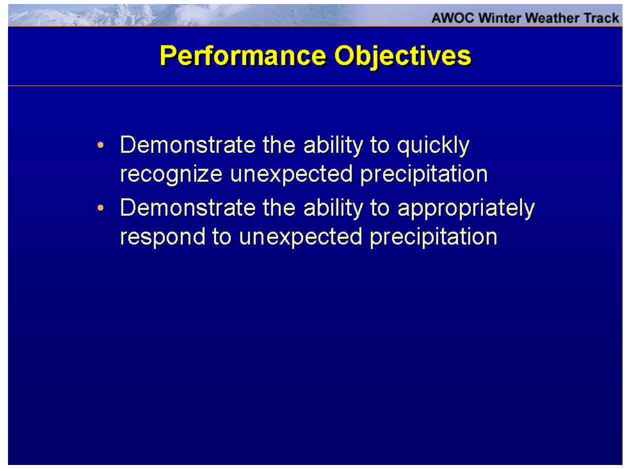


6. Performance Objectives

Instructor Notes: There are two performance objectives. First, you should be able to demonstrate the ability to quickly recognize unexpected precipitation areas. And second, You should be able to demonstrate the ability to respond appropriately to unexpected precipitation areas.

Student Notes:



7. The Methodology

Instructor Notes: As previously mentioned, the methodology is comprised of five elements (or steps). The first two – monitor conditions and recognize forecast departure – make up the recognition phase of the methodology. Forecasters need to recognize as early as possible when departures from the current forecast are occurring. The last three elements – diagnose cause for forecast departure, forecast persistence, and update forecast – represent the response phase of the methodology. Ultimately, the forecast update needs to be scientifically sound, decisive, and timely. Any operational forecaster who has responded to unexpected conditions -- in other words, every forecaster -- should find the methodology essentially review.

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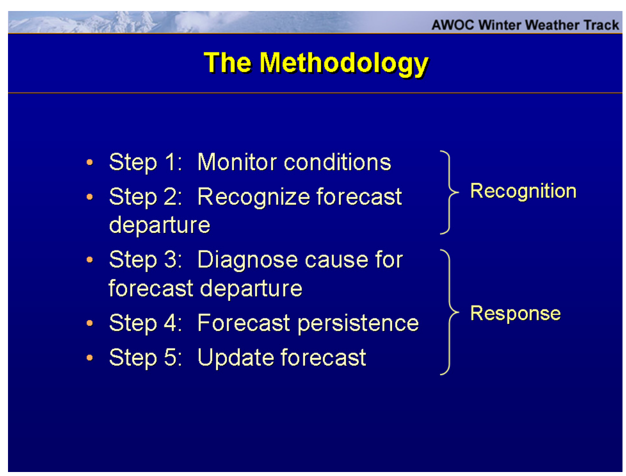

8. The Methodology: Steps 1 & 2

Instructor Notes: The first step of the methodology is to monitor conditions. Within the context of the current forecast, monitor all observational data, including: surface observations, upper air data, satellite data, profilers, webcams, and spotter reports. It is critical for forecasters to maintain a continuous weather watch so that trends in observational data can be recognized and assessed. Step two is to recognize forecast departures. Ideally, forecasters will anticipate forecast departures prior to their occurrence. However, in other situations, forecast departures won't be recognized until they have already occurred. Examples might include surface reports of freezing rain or spotter reports of unexpectedly high snowfall amounts. Especially during complex weather situations, forecasters should initially focus on forecast departures that could potentially have the highest impact on public safety.

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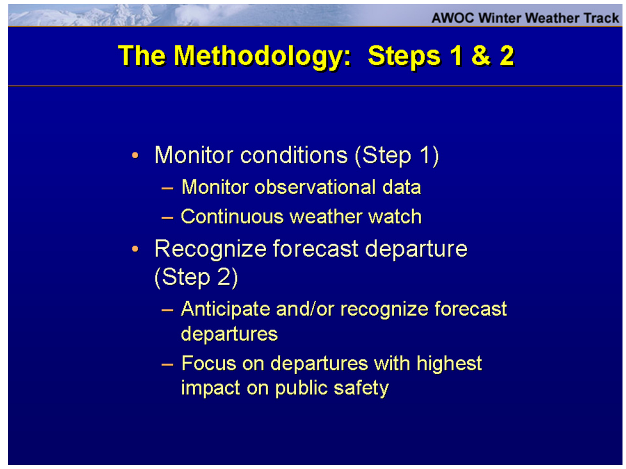

9. The Methodology: Step 3

Instructor Notes: Step three of the methodology is to diagnose the cause for the forecast departure. In other words, what is causing the weather to deviate from earlier expectations? Banded precipitation associated with frontogenetical circulations, higher precipitation rates due to elevated instability, and unexpected precipitation microphysics are all examples of processes which can cause wintertime precipitation to change character or intensity. As with any diagnosis, forecasters need a disciplined and systematic approach when applying diagnostic tools, conceptual models, and their local knowledge.

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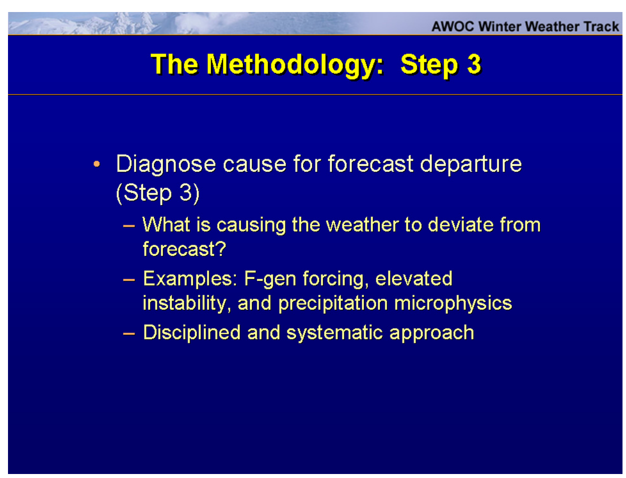

10. The Methodology: Steps 4 & 5

Instructor Notes: Once the cause for the forecast departure has been accurately diagnosed, the next step (step four) is to forecast the persistence of those conditions. For example, if snow has unexpectedly changed to freezing drizzle due to the disruption of ice processes by midlevel drying, how long will the drying persist? 2 hours? 6 hours? Will the midlevel drying impact other areas? These are the types of questions forecasters need to ask, and to accurately assess, since the answers will impact how the forecast is updated. All of these questions brings us to step 5, updating the forecast. Our ultimate goal (of course) is to provide the most accurate forecasts to help enhance public safety. Steps 4 and 5 of the methodology are closely related, since an accurate assessment in step 4 will directly impact the final response forecasters make in step 5. And without an accurate assessment of the persistence, forecasters will often find themselves playing catch-up with multiple forecast updates.

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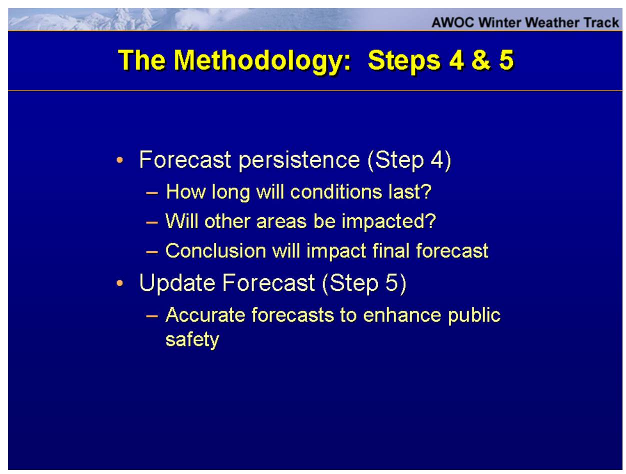


11. Question: Five steps of Methodology

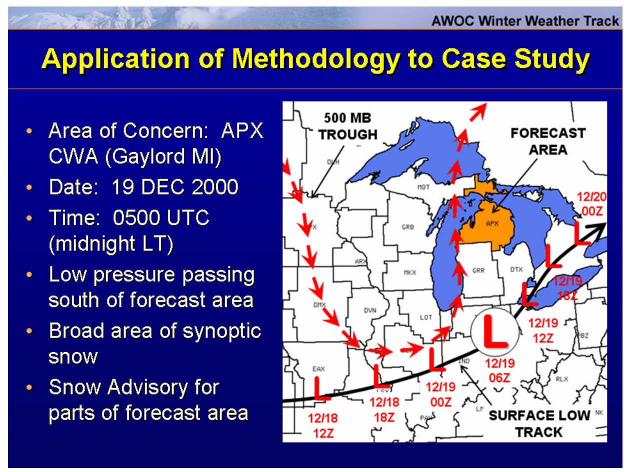
Instructor Notes: Take a moment to complete this interactive quiz question.

Student Notes:

12. Application of Methodology to Case Study

Instructor Notes: We'll now apply the methodology to a short case study. You're at the Gaylord, Michigan forecast office... it's December 19th... the present time is 05 Z, or midnight local time. As the event begins, a deepening 500 mb trough is located over the western Great Lakes, and a surface low (presently over northeast Indiana) is forecast to move across extreme western Lake Erie into southern Ontario. Broad synoptic snow is occurring across the region, and a Snow Advisory is in effect for parts of the forecast area.

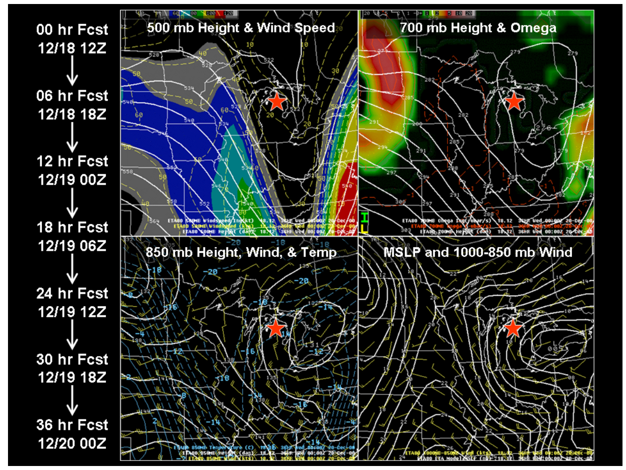
Student Notes:



13. Synoptic Overview

Instructor Notes: We'll now step through a 4-panel display from the December 18 12 Z run of the Eta. The 4-panel depicts 500 mb height and wind (in the upper left); 700 mb height and omega (in the upper right); 850 mb height, wind, and temperature (in the lower left); and mean sea level pressure and 1000-850 mb wind (in the lower right). As a point of reference, the red star denotes your location within the Gaylord forecast area. As we move to 18Z December 18 (roughly 12 hours prior to the current time) we see the 500 mb trough deepening over the upper Mississippi Valley, with a 90 kt jet lifting northeast into the Ohio Valley. Similarly, a closed 700 mb low is positioned in the vicinity of Iowa, with an impressive area of 700 mb lift over the western Great Lakes. WAA is noted in advance of the 850 mb low, and the surface low at this time is located near St. Louis. By 00Z December 19, both the 500 and 700 mb lows continue to deepen. Meanwhile, the centers of circulation at 850 mb and the surface have moved into Illinois. By 06Z December 19 (close to the current time), we see the 500 and 700 mb lows near Chicago. Strong 700 mb ascent is noted across Lower Michigan and, not surprisingly, is coincident with the location of the left exit region of the 500 mb jet streak. 850 mb WAA continues to spread into Lower Michigan at this time, as easterly flow develops from the surface through 850 mb. Over Lake Huron, 850 mb temperatures are around -13 degrees C at this time, and with lake temperatures around +4 degrees C, lake enhancement is possible. By 12Z December 19, the 500 and 700 mb troughs are passing through the region, as the 850 mb and surface lows move into extreme southeast Lower Michigan. The low level flow shifts from east at 12Z...to northeast by 18Z...and finally to north by 00Z as the system pushes steadily off to the east northeast.

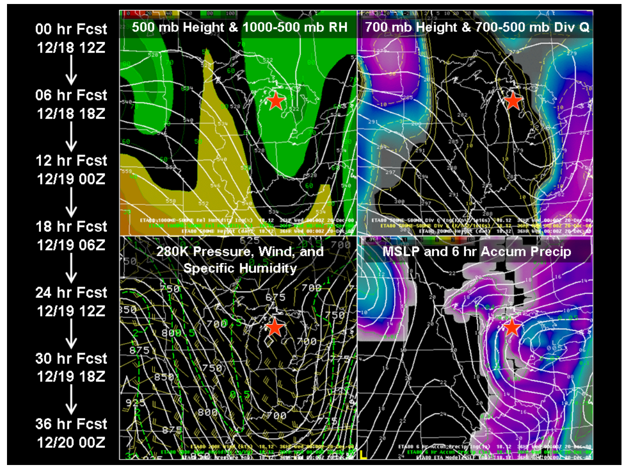
Student Notes:



14. Synoptic Overview

Instructor Notes: Here is another 4-panel display from the December 18 1200 Z run of the Eta. This 4-panel depicts 500 mb height and 1000-500 mb relative humidity (in the upper left); 700 mb height and 700-500 mb Layer Q-vector divergence (in the upper right); 280K Pressure, wind, and specific humidity (in the lower left); and mean sea level pressure and 6-hour precipitation accumulation (in the lower right). Consistent with the previous 4-panel, by 18Z December 18, we see an impressive area of QG forcing for ascent moving into the western Great Lakes, as deep layer (1000 to 500 mb) moisture gradually increases. By 00Z December 19, deep layer moisture and QG forcing for ascent both increase across Lower Michigan. Meanwhile, the 280K isentropic surface suggests isentropic plugged, with specific humidity (a measure of absolute moisture) of 1 to 1 ½ gm/kg at this level. By 06Z December 19 (close to the current time) forcing for ascent appears to be near it's maximum, with both the QG and the isentropic analysis plots supporting strong lift. It is interesting to note that while deep layer relative humidity values are high at this time (exceeding 80%), specific humidity values on the 280 K surface (located between 700 and 750 mb) are only 1 to 1 ½ gm/kg. By 12Z December 19, QG support for ascent is just beginning to shift off to the east, as closed circulations at both 500 and 700 mb move into Lower Michigan. The trend continues at 18Z December 19... QG support has pushed off the east. Similarly, the 280 K isentropic analysis shows that isentropic lift is about to end. And finally, by 00Z December 20, large-scale support for lift has entirely shifted to the east. Eta QPF fields support approximately one third of an inch water equivalent for the 12 hr. period ending 12Z December 19th...with another two tenths of an inch for the 12 hr. period ending 00Z December 20th.

Student Notes:



15. The Current Forecast

Instructor Notes: The current forecast includes a snow advisory for the rest of tonight (depicted in yellow) for eastern and southern portions of the forecast area. Between 3 and 6 inches of snow are expected in this area. As previously noted, organized ascent will pass through the region the remainder of the night, and while deep layer relative humidity is high, specific humidity in the 700-750 mb layer is only approaching 1.5 gm/kg. Some lake enhancement is expected over eastern areas, thanks to easterly low level winds and lake to 850 mb temperature differentials of around 17 degrees C.

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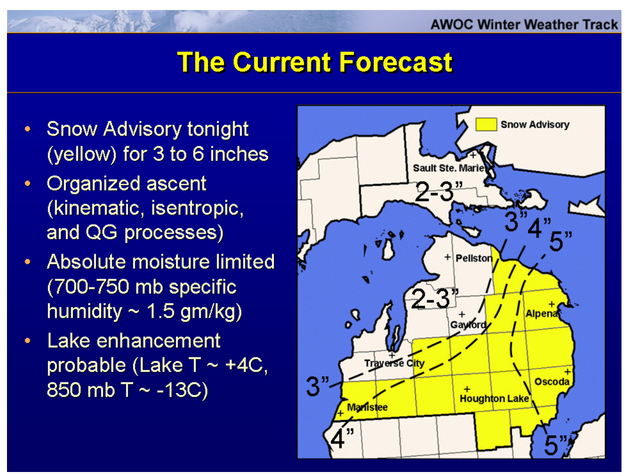
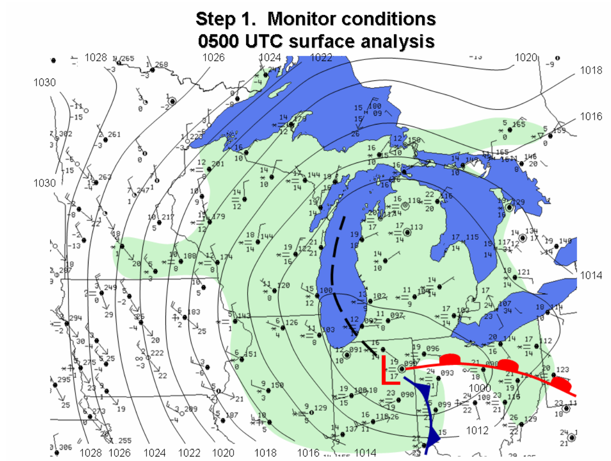


16. Surface Analysis

Instructor Notes: Now that we have reviewed the current forecast, as well as the supporting model data, we will step through the methodology. As you recall, step one is “monitor conditions”. We begin by reviewing the 05Z surface analysis, which shows the surface low over northeast Indiana. Light to moderate snow is falling across much of Michigan and Wisconsin, as well as portions of Illinois, Indiana, and Ohio. With the exception of one freezing rain report in northern Ohio, all precipitation is falling as snow.

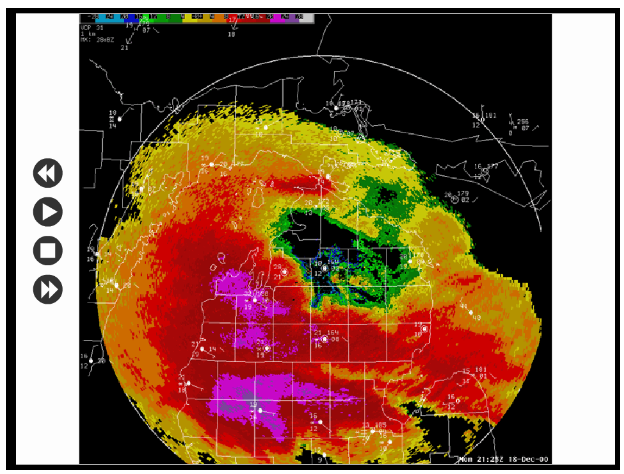
Student Notes:



17. Radar Loop

Instructor Notes: A loop of the Gaylord WSR-88D from roughly 2130 Z to the present time shows snow overspreading the region from southwest to northeast. During this time period, snowfall intensities from a radar perspective don't appear to be particularly high. For the most part, maximum reflectivities are in the 20 to 24 dBZ range.

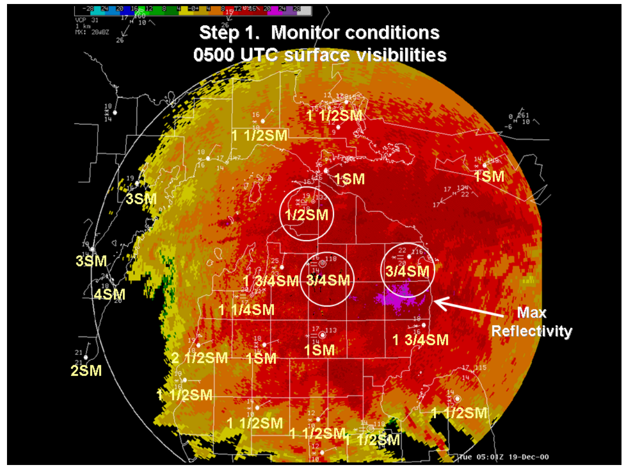
Student Notes:



18. Visibilities

Instructor Notes: Current surface visibilities generally range from 1 to 2 miles across the forecast area, indicative of light to moderate snow. The exceptions are Pellston, Gaylord, and Alpena – where visibilities range from ½ to ¾ mile. It's worth noting that only during the past hour have the visibilities at these locations fallen below 1 mile. At the present time, the highest radar reflectivities are located along the Lake Huron shoreline just south of Alpena.

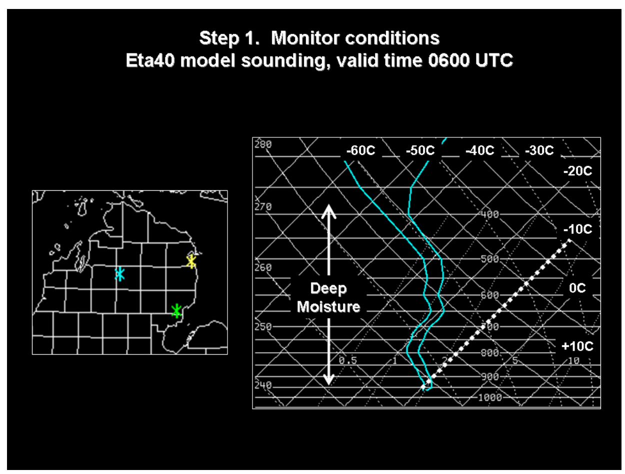
Student Notes:



19. Model Sounding

Instructor Notes: An Eta model sounding for a location near the center of the forecast area, valid at 06Z, shows moisture extending from the surface through approximately 400 mb. From a snow growth standpoint, it is worth noting that nearly the entire sounding is colder than -10 degrees C. This finding is consistent with our previous observation of the relatively cold 850 mb temperatures.

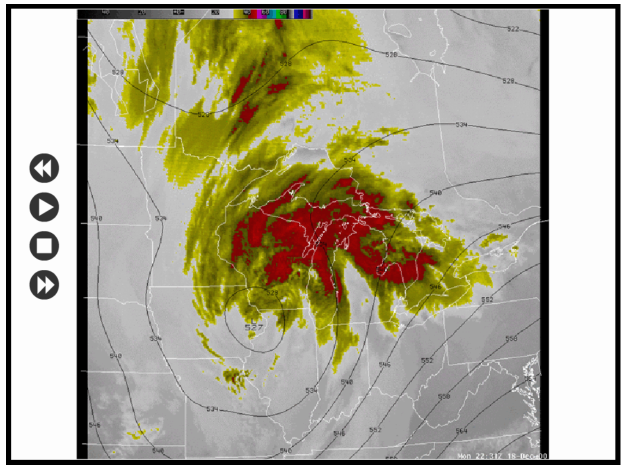
Student Notes:



20. IR Satellite Loop

Instructor Notes: Finally, we conclude step one (monitor conditions) by reviewing IR satellite data. This loop is valid from roughly 2230 Z to the present time. 500 mb heights are overlaid. The mid-tropospheric circulation center is clearly visible, and strong vertical ascent can be inferred from the expanding area of cold cloud tops across the northern Great Lakes.

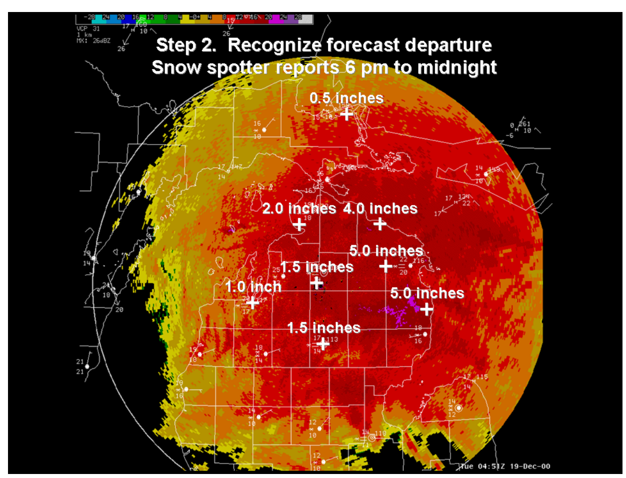
Student Notes:



21. Spotter Reports

Instructor Notes: Next, we move to step 2 -- Recognize forecast departures. While the observational data up to this point has supported widespread snow, nothing has stood out to suggest heavy snowfall. That is about to change as midnight spotter reports begin to arrive. Over central and western parts of the forecast area, spotter reports show up to two inches of snow during the past six hours. These reports are consistent with the current forecast. Over eastern areas, however, spotter reports are heavier. At Rogers City, 4 inches is reported, while 5 inches is reported by two spotters around Alpena. In this case, all spotter reports are considered to be very reliable. With 3 to 6 inches of snow forecast for tonight, and 5 inches having already fallen by midnight in some areas, it appears that forecast snowfall amounts may be underdone, and that warnings might be justified for some counties.

Student Notes:



22. Question: What comes next?

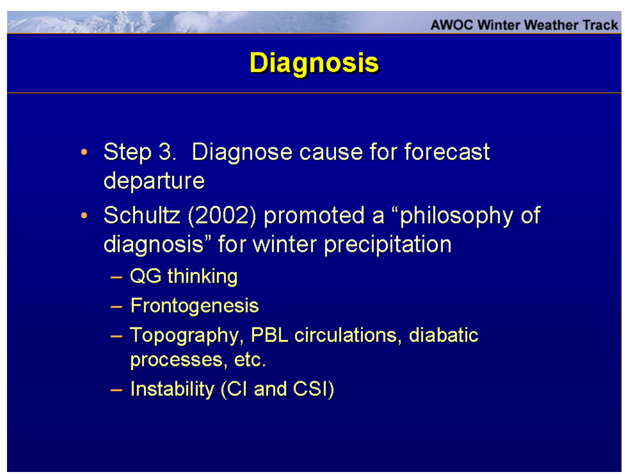
Instructor Notes: Take a moment to complete this quiz question.

Student Notes:

23. Diagnosis

Instructor Notes: In step three, we diagnose the cause for the forecast departure. Schultz (2002) promoted a “philosophy of diagnosis” for winter precipitation. It was suggested that if you see something on radar and you don’t know what is causing it, your first attempt to account for it should be QG thinking (in other words, DPVA and/or warm advection). If QG diagnostics don’t provide an answer, then try frontogenesis at different levels. If frontogenesis fails to account for the precipitation, then try other processes such as orographic lift, PBL circulations, and diabatic processes. The role of instability should also be considered, remembering that it’s affect is to modulate the response to the given forcing.

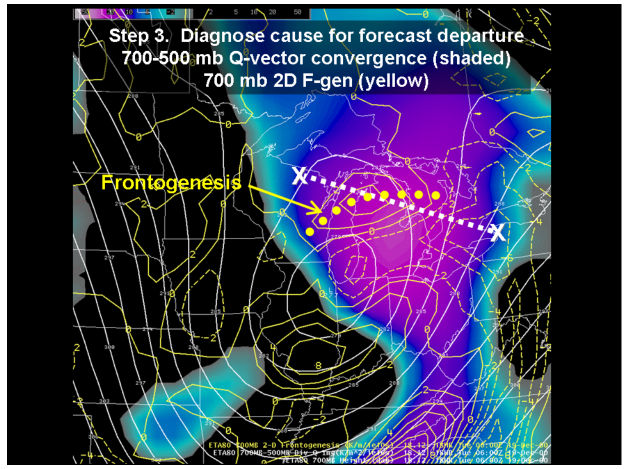
Student Notes:



24. QG Forcing and Frontogenesis

Instructor Notes: We’ll now attempt to apply this philosophy of diagnosis to our case study. Shown on this image is 700 mb height contours, 700-500 mb layer Q-vector convergence, and 700 mb 2D frontogenesis – valid at 06 Z. As previously noted, strong QG support for ascent is occurring across the region. Also, note the band of positive Frontogenesis oriented west to east across Lower Michigan, in an area likely associated with 700 mb deformation. We'll now construct a cross-section through the area of frontogenesis so that we can better assess the associated forcing and thermodynamic regime. The cross-section will extend from northern Wisconsin to near Buffalo.

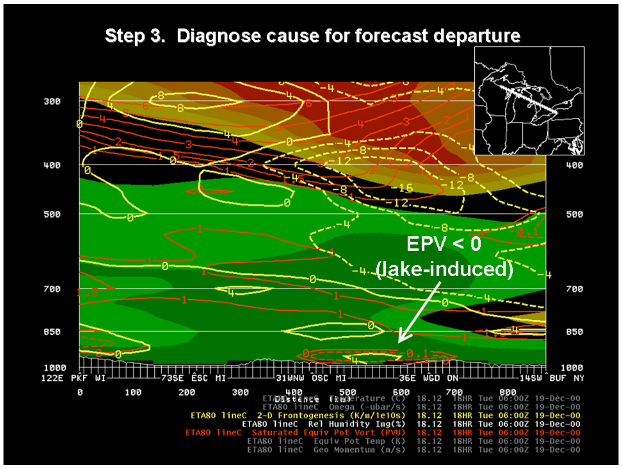
Student Notes:



25. Cross-Section

Instructor Notes: Initially plotted on the cross section is 2-D Frontogenesis (in yellow), and relative humidity (with values greater than 70% shaded green). Note the max in frontogenesis noted previously on the plan view. Model omega is now overlaid. A broad area of ascent is noted near the center of the cross section, with the max ascent (not surprisingly) located on the warm side of the 700 mb frontogenesis max. Model omega, relative humidity, and isotherms reveal an excellent thermodynamic regime for efficient snowflake growth near the center of the cross section (near Lake Huron). Note the juxtaposition of strong vertical motion, high relative humidity, and temperatures around -15 degrees C – consistent with the cross hair signature. A cursory look at equivalent potential temperature and geostrophic momentum shows relatively high static stability above the boundary layer. The relative stability aloft is supported by saturated equivalent potential vorticity (shown in red), which is overlaid with 2-D frontogenesis. Shallow lake-induced instability is noted in the vicinity of Lake Huron. Aloft, however, there is little evidence of instability aloft across northern Lower Michigan.

Student Notes:



26. Radar and Surface Data

Instructor Notes: Continuing with step 3 of the methodology we take a closer look at radar and surface observations from earlier in the evening (around 0330 Z). Three aspects of this image are worth noting. First, subtle convective elements can be seen in the radar data embedded within the synoptic snow over northern Lake Michigan and Lake Huron, though radar reflectivities are weak. Next, note the low level wind convergence in the vicinity of Alpena. In fact, the two coastal wind reports and the two Lake Huron ship reports support the existence of a circulation center southeast of Alpena. Lastly, higher radar returns are found south of Alpena, near the location of the spotter reports, and coincident with the cross hair signature previously noted in the cross section.

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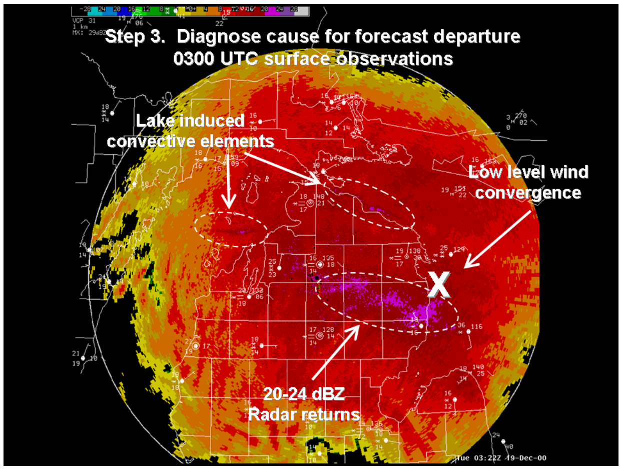


27. Question: The critical observation...

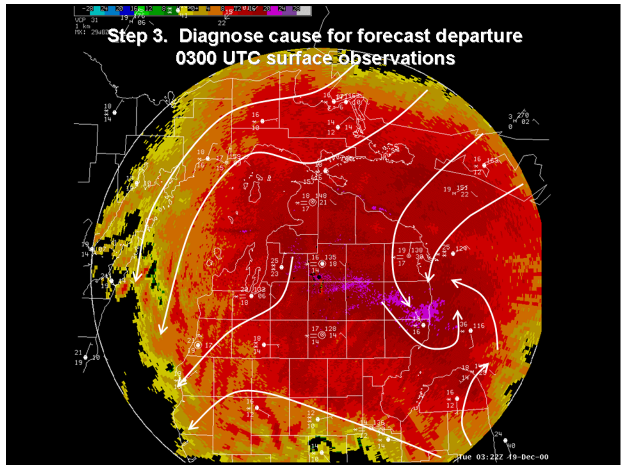
Instructor Notes: Take a moment to answer this question.

Student Notes:

28. Low Level Circulation

Instructor Notes: The low level circulation over western Lake Huron, as revealed by surface observations, is the most likely culprit for the locally heavy snowfall around Alpena. A subjective streamline analysis shows the apparent circulation. Note that the circulation is supported by both of the offshore ship reports, as well as the southerly flow shown in surface observations near the tip of Michigan's thumb.

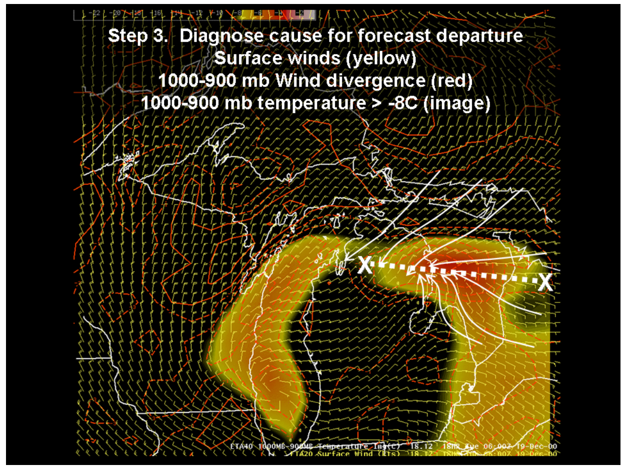
Student Notes:



29. Convergence Over Lake Huron

Instructor Notes: To examine the origin of this low level circulation, we next examine 40 km Eta output of surface wind (in yellow), 1000-900 mb wind divergence (in red – such that the dashed contours show boundary layer convergence), and 1000-900 mb temperature (with values warmer than -8 degrees C shown in shades of yellow and red). We start at 12 Z the morning prior to the event. Note the low level convergence and heat plume over eastern Lake Huron, associated with west to northwest winds over Lake Huron. Initially, the plume remains stationary and, in fact, intensifies. By 00z, as the synoptic low approaches from the southwest, winds become easterly. This causes the heat plume and area of low level convergence to get drawn back to the west across Lake Huron. By 03Z, the heat plume reaches northeast Lower Michigan, and by 06Z the convergence and heat plume are located near the location of the heavy snowfall. A subjective streamline analysis clearly shows the strong convergence coincident with the low level heat plume. We'll now construct another cross section. This time extending from north central lower Michigan across central Lake Huron, to just south of Georgian Bay.

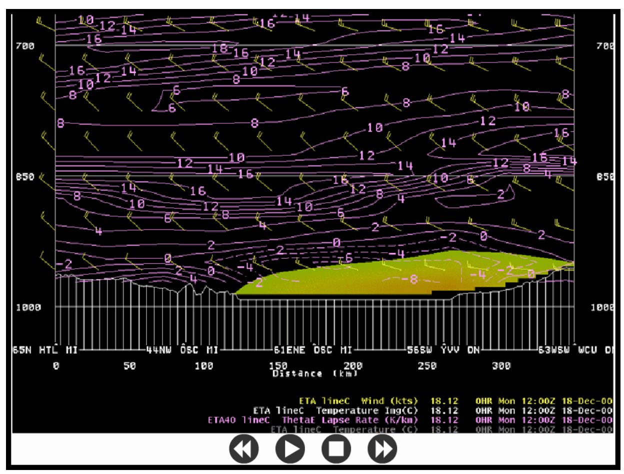
Student Notes:



30. Cross-Section Loop

Instructor Notes: Depicted on this cross-section loop over central Lake Huron are winds (in yellow), theta-e lapse rate (in purple), and temperature (with values warmer than -8 degrees C shown in shades of yellow and red). Lake Huron is at the center of the cross-section. Note that as boundary layer winds become east, the lake induced heat plume intensifies and moves to the west. As winds become north late in the loop, the heat plume shifts back to the east. Also, note the decrease in static stability over north-east Lower Michigan, as depicted by the theta-e lapse rate values. This occurs in response to both the lake induced heat plume, and the strong, synoptic scale ascent.

Student Notes:

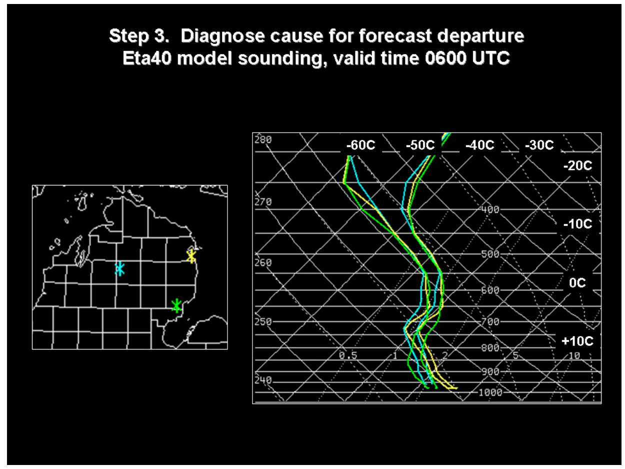


31. Model Soundings

Instructor Notes: We conclude our diagnosis in step 3 of the methodology by looking at three forecast model soundings, all valid at 06Z. The first sounding (in blue) is over the central portion of the forecast area (well inland from the Great Lakes). It shows deep moisture, but with very little of the moisture at temperatures warmer than -10 degrees C. The next sounding (in yellow) is along the Lake Huron shoreline about 60 miles south of

Alpena. It also shows deep moisture, but with a slightly deeper portion of the sounding warmer than -10 degrees C. The final sounding (in yellow) is near Alpena. It shows the boundary layer heat plume, abundant moisture below 800 mb, steeper lapse rates below 800 mb, and an approximately 3500 foot layer warmer than -10 degrees C. In other words, it indicates that in addition to the overlying synoptic moisture, lake-induced processes are also occurring. Compared to the other forecast model soundings, for the reasons just stated, this sounding should be a much better producer of heavy snowfall.

Student Notes:



32. Question: And the diagnosis is...

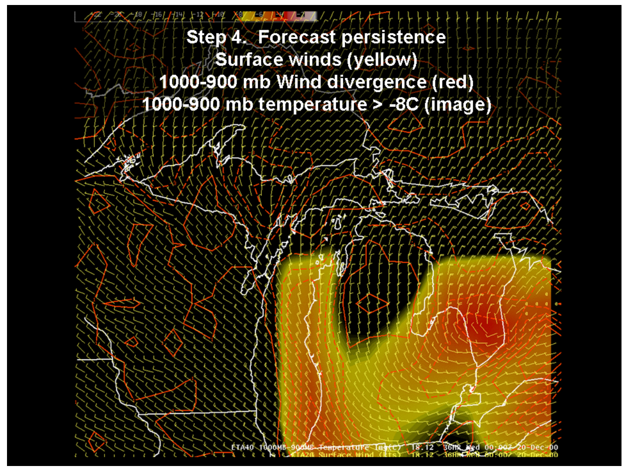
Instructor Notes: Take a moment to complete this question.

Student Notes:

33. Eta40 Loop

Instructor Notes: Now that we have diagnosed the lake-induced heat plume and convergence over Lake Huron as the main cause for the reports of heavier snowfall, let’s move on to Step 4 – which is to forecast the persistence of convergence area. To do this, we’ll once again examine 40 km Eta output of surface wind (in yellow), 1000-900 mb wind divergence (in red – such that the dashed contours show boundary layer convergence), and 1000-900 mb temperature (with values warmer than -8 degrees C shown in shades of yellow and red). At 06Z, the previously noted heat plume and area of strong convergence can be seen just south of Alpena. Moving forward in time, we note that the heat plume remains over northeast lower Michigan, as the convergence slowly sags southward. By late afternoon (or roughly 21Z) the convergence area is forecasted to have weaken. Also, remember that during this time, synoptic lift associated with the large-scale system is pushing rapidly east of the area with the upper trough, so little in the way of large-scale ascent is occurring by afternoon.

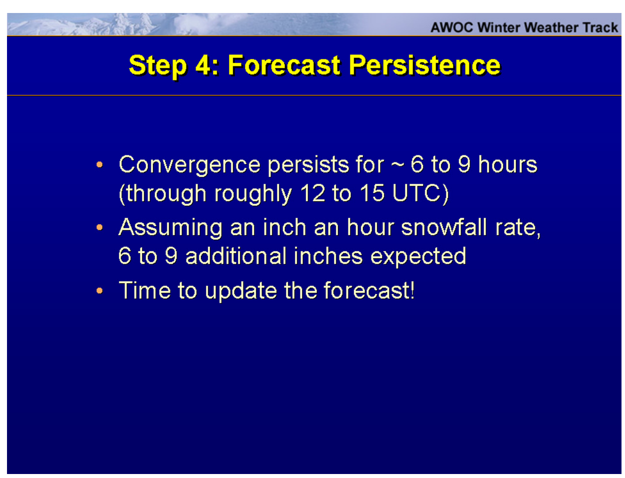
Student Notes:



34. Step 4: Forecast Persistence

Instructor Notes: Based on this very brief assessment, strong convergence and enhanced snowfall rates will likely persist over northeast Lower Michigan (near and south of Alpena) for the next 6 to 9 hours (until roughly 12 to 15Z). Assuming a conservative snowfall rate of an inch an hour...an additional 6 to 9 inches of accumulation can be anticipated near Lake Huron. And finally, the last step of the methodology (of course) is to update the forecast.

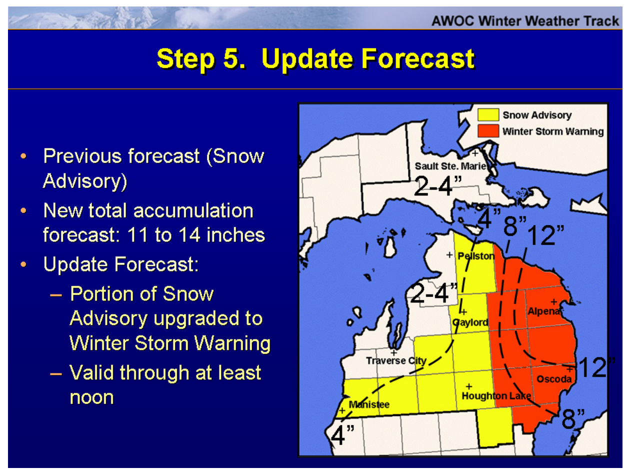
Student Notes:



35. Step 5. Update Forecast

Instructor Notes: As you recall, the initial forecast called for 3 to 6 inches of snow over eastern and southern parts of the forecast, and a Snow Advisory was in effect. Based on the spotter reports and the subsequent assessment of the situation, total snow accumulations of around a foot are now expected by midday over northeast lower Michigan near Lake Huron. Consequently, the forecast will be updated for the higher snowfall amounts, and portions of the Snow Advisory will be upgraded to a Winter Storm Warning – that will extend through about noon.

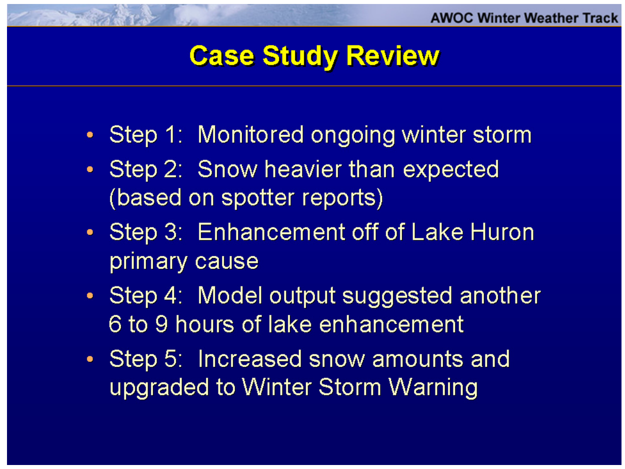
Student Notes:



36. Case Study Review

Instructor Notes: Let’s briefly review how we applied all five steps of the methodology to the case study. In step 1 we monitored conditions (this included surface observations, radar, satellite, and spotter reports). In step 2, based on several spotter reports, we noted that snow was falling heavier than originally anticipated. In step 3, we reviewed several meteorological aspects of the event, and concluded that the heavy snow was most likely being caused by enhancement off of Lake Huron. We determined in step 4 that the low level enhancement would likely persist for another 6 to 9 hours. And finally in step 5, we updated the forecast to increase snow amounts and to upgrade parts of the original snow advisory to a winter storm warning.

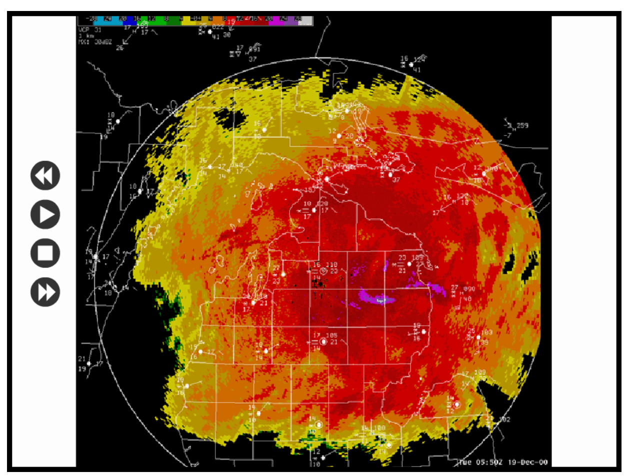
Student Notes:



37. What Happened?

Instructor Notes: You may be wondering what actually happened in this event? A loop of the Gaylord WSR-88D from roughly 06 UTC through 11 UTC reveals a few interesting things. First, note the persistent high radar returns streaming in from Lake Huron near and just south of Alpena. These higher returns coincide very nicely with the center of circulation noted in the surface observations and model data. In fact, by the end of this loop, at least one center of circulation (void of radar returns) can be seen south of Alpena. How intense was the convection? Well, the 09Z observation at Alpena indicated heavy snow with thunder.

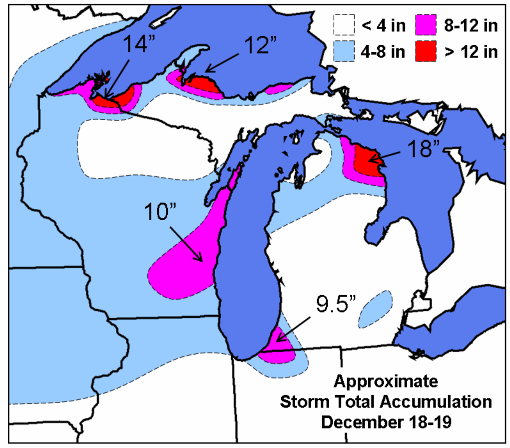
Student Notes:



38. Observed Snowfall

Instructor Notes: From 12 to locally 18 inches of snow during this event over northeast Lower Michigan. Clearly, other parts of the Great Lakes received locally heavy snowfall, as well. In all cases, the enhanced snow occurred downwind of the Great Lakes. Areas receiving heavy snowfall included: parts of Upper Michigan, northern and eastern Wisconsin, extreme southwest Lower Michigan, and northern Indiana.

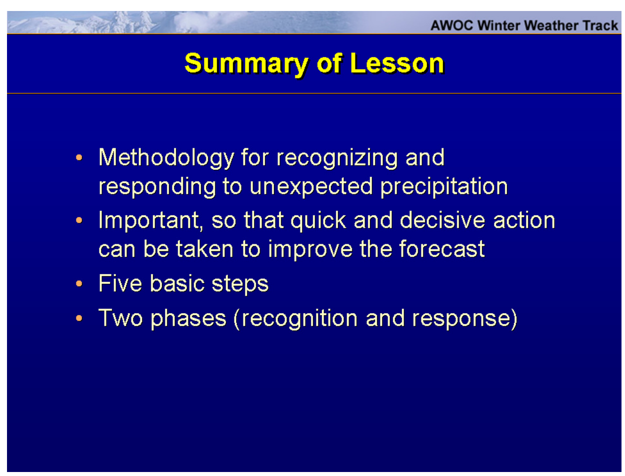
Student Notes:



39. Summary of Lesson

Instructor Notes: In this lesson, through the use of a short case study, we outlined a methodology for recognizing and responding to unexpected precipitation areas. While this methodology is likely intuitive to most forecasters, it is importance so that quick and decisive action can be taken to improve the forecast. As you recall, the methodology was comprised of five basic steps and two phases. The first two steps – monitor conditions and recognize forecast departure – made up the recognition phase of the methodology. The last three steps – diagnose cause for forecast departure, forecast persistence, and update forecast – represented the response phase of the methodology.

Student Notes:



40. Questions???

Instructor Notes: After going through this lesson if you have any questions, first ask your SOO. Your SOO is your local facilitator and should be able to help answer many questions. If you need additional info from what your SOO provided, send an E-mail to the address on the slide. This address sends the message to all the instructors involved with this IC. Our answer will be CC'd to your SOO so that they can answer any similar questions that come up in the future. Thanks for your time and good luck on the exam!

Student Notes: